A SPECIAL TESTING PROBLEM AT IBM

Detection of Flexure Instability in Drum Memory Reading Heads

 Prepared for the Stanford Engineering Case Program by Ken J. Waldron, Department of Mechanical Engineering, University of New South Wales, with the support of the National Science Foundation.

1. A problem in the production of drum memory units.

One of the product lines of the San Jose establishment of IBM Corporation is a range of drum memories for computers. The principle employed in these devices is that of the tape recorder -- storage of information as magnetized areas in a film of magnetic material. The magnetic film is deposited on the surface of the drum. Information is recorded and read by means of "heads" which contain wire coils. In order to record, a current is passed through a coil creating a magnetic field which magnetizes a small area of the film. A spot on the film is read by passing it under a coil. The magnetic field generates an e.m.f. in the coil.

One type of drum memory has 440 heads arranged on 40 racks. Each head has two coils. Exhibits 1 and 2 show, respectively, a head from this unit, and a schematic diagram of the arrangement of the head in the rack. The racks are parallel to the drum axis and are staggered so that each coil covers a different strip of the drum surface. When a head is to be used, a pneumatic plunger, shown in Exhibit 2 pushes it 0.045 inches closer to the surface. This is accompanied by bending of the flexure supporting the head. An air bearing is formed between the head and the drum which helps to maintain the head a very small distance from the magnetic surface. During normal operation the head never contacts the drum. The six leaf springs which make up the flexure also function as electric connections to the coils in the head.

If the head touches the drum it wears the magnetic film and may, if contact occurs frequently enough, wear it out. More importantly, it also disturbs any information which might be stored in the portion of the surface which it contacts. This can occur after even a single contact. The company views this type of failure very seriously. Reliable storage is of great importance in computer memories. Even a small change in the information stored can cause costly system failures.

During the development of the unit it was found necessary to reduce the occurrence of contacts. An investigation showed that many were associated with heads which showed a defect called "oil-can" by the engineers. Oil-can occurs when one of the six springs in the flexure is somewhat longer than the others. Since it is, effectively, a long thin column in compression, it buckles into a bow. If the flexure is bent so as to increase the bow, it will pop to the other side (refer to Exhibit 3).* The same effect can be produced by taking a fairly stiff piece of paper, and pushing its edges in to produce a bow (Exhibit 3). If the side of the paper on the outside of the bow is pressed in, the bow will pop to the other side. The unevenness in the lengths of the leaves, which sometimes occurs, is a result of the process in which the thermoplastic head is molded about the leaves. This involves high temperature and pressure. If, for example, the temperature field during molding were uneven, the leaves might well have differing lengths after cooling.

---

*This effect is deliberately produced in Micro Switches (ed.).

As a result, heads coming from the production line are inspected under the microscope. If there is any evidence of a bowed leaf they are rejected. However, the number of heads rejected in this manner is considerably larger than would be expected from the incidence of failures of the drum unit. As a result, a stockpile of several thousand rejected heads was built up over a period of a few months. This represented a substantial loss of money for the company. Therefore, it was decided that an attempt should be made to devise a more accurate test, to distinguish those heads in which the oil-can was not serious. Another factor which later became important was a need to do this quickly. The reason for this was that, unless they are maintained in an environment with controlled temperature and humidity, the heads deteriorate. Provision for environmental control is, of course, included in the drum unit. However, the rejected heads were not protected and, therefore, if they were to be salvaged it would have to be done quickly.

2. <u>Chris Jako</u>

The department developing the unit requested that a machine be designed to detect and measure oil-can. The job was given to Chris Jako of the Mechanical Analysis section. (The function of the analysis section is approximately that of an in-house consulting group).

Chris Jako, a native of Budapest, Hungary, came to this country in 1950 to study electrical engineering. He received his BS and MS from the University of New Mexico. After a few years at the University of California at Berkeley, both as

student and research staff member, he obtained an MS in Mechanical engineering. Chris joined IBM in San Jose in 1964 and has been engaged in electromechanical instrumentation since then.

After acquainting himself with the problem, Chris thought that it might be possible to detect oil-can by observing the force-displacement curve of the flexure. As can be observed from the experiment of Exhibit 3, a sudden change in force can be expected when a leaf pops. Chris therefore decided to build a machine to measure the force needed to bend the flexure as a function of displacement. Using materials at hand, Chris, with the help of a technician, put together the machine shown in Exhibit 4. This consists of a spring clamp which grips the head and a fork which fits around the head base to raise or lower it. The fork is on the end of a thin steel cantilever beam at the middle of which is a semiconductor strain gauge known as a "pixie". As the beam bends the strain gauge, resistance changes and provides a measure of the force bending the flexure. The other end of the beam is fixed in a slide which is raised and lowered by means of a micrometer screw. The micrometer screw is turned by a timing belt driven by a variable speed, reversible, d.c. motor with an internal worm gearset. The micrometer was used because of its fine thread and availability. A lever set in the slide carrying the cantilever operates two microswitches which contain the deflection within allowable limits.

Using this machine, Chris found that oil-can did produce irregularities in the force-displacement curve of the flexure

and that the sizes of the irregularities could be correlated with visual estimates of the severity of the oil-can. Exhibit 5 is a report comparing force-displacement traces and visual observations for 24 heads.

In view of the good performance of his experimental machine, Chris decided to try to convert it so that it could be used to test heads on a production basis. To do this, it was necessary to have some way of measuring the magnitude of the bump in the force-displacement curve. Chris decided to do this by differentiating the force signal. This would give him a nearly constant output signal, except when a leaf popped, when a cluster of pulses would be output. He could then use the pulses to drive a flip-flop circuit which would turn on a light.

Chris spent the next couple of weeks designing, building, and testing this circuit. A signal proportional to the resistance changes in the pixie was generated in a bridge circuit, fed to a differentiator, the output rectified and used to drive a flip-flop. The flip-flop only responded to signals above a particular threshold level. The signal driving the flip-flop was taken from the rectifier through a potentiometer. This permitted the sensitivity of the unit to be varied. The circuit is shown in Exhibit 6. The oscilloscope jacks and displacement input were not originally included.

Chris next got a technician to package the circuit in a smart looking box and sent the unit off to the product engineering division. It came back shortly thereafter with a request for modifications. The product engineering division requested that

output jacks for an oscilloscope be added. They also requested that a displacement transducer be added to give a plot of force against displacement. The unmodified unit was measuring force as a function of time. However, the displacement-time traces of Exhibit 5 are quite linear so this was not judged important.

Chris added the output jacks as requested and installed a potentiometer on the micrometer screw to measure displacement. He then sent it back to the product engineering division.

3. Joe Pelzner

Having satisfied themselves that Chris' prototype oil-can detector would work, the product engineering division passed it on to the manufacturing engineering division. Joe Pelzner was given the job of using it to test the backlog of rejected heads.

The first thing Joe did was to have a cover made to go over the exposed components of the machine. This was constructed of clear plastic which happened to be available. The clamp remained outside the cover and the end of the beam projected from an opening in the cover allowing the detector to be operated.

Joe had next to devise some means by which an inspector could tell quickly from the force-displacement curve plotted on an oscilloscope, whether the irregularities were within permissible limits. He decided to use a storage scope which can store and display the complete plot, rather than just a dot tracing the curve. To provide a measure of the permissible size of irregularities he made an overlay with a straight line on it and three circles centered on the line. The operator places

the overlay on the screen with the line along the trace. Any irregularity must fit inside one of the circles, otherwise the unit is rejected. The indicator light is not, at present, used.

Joe's biggest problem was the fragility of the pixies. The upper prong of the fork on the end of the cantilever was discarded to simplify the operation of inserting a head and lessen the chance of pushing on the beam and breaking the pixie.

Joe took time off to get married. When he returned the pixie was broken. He sent it back to Chris for replacement. When it was returned a new problem arose. The old pixie had been quite linear but the new one was not so. Joe had to make a new overlay corresponding to the average curvature of the force-displacement curve produced by this pixie. He also had to take account of variation in the size of the permissible irregularity caused by the non-linearity.

Despite these problems, the rejected heads were tested and about a third of them were salvaged as useable. This effected a worthwhile saving.

The oil-can detector is not, at present, in use. For several reasons it is preferable to wait until a substantial number of rejects builds up and then run them all through over a period of a few days. Once the operator is familiar with the machine it is possible to test 600 to 800 heads per day. This is far greater than the daily reject rate. Also the storage scope is an expensive piece of equipment and it is not justifiable to keep one for this purpose alone. This means that one has to be borrowed from elsewhere whenever the detector is to

be used.

Because it was necessary to test the backlog of rejected heads as soon as possible, the oil-can detector was prèssed into service while still essentially an experimental device. However, it was successful and no redesign is envisaged.

LIST OF EXHIBITS

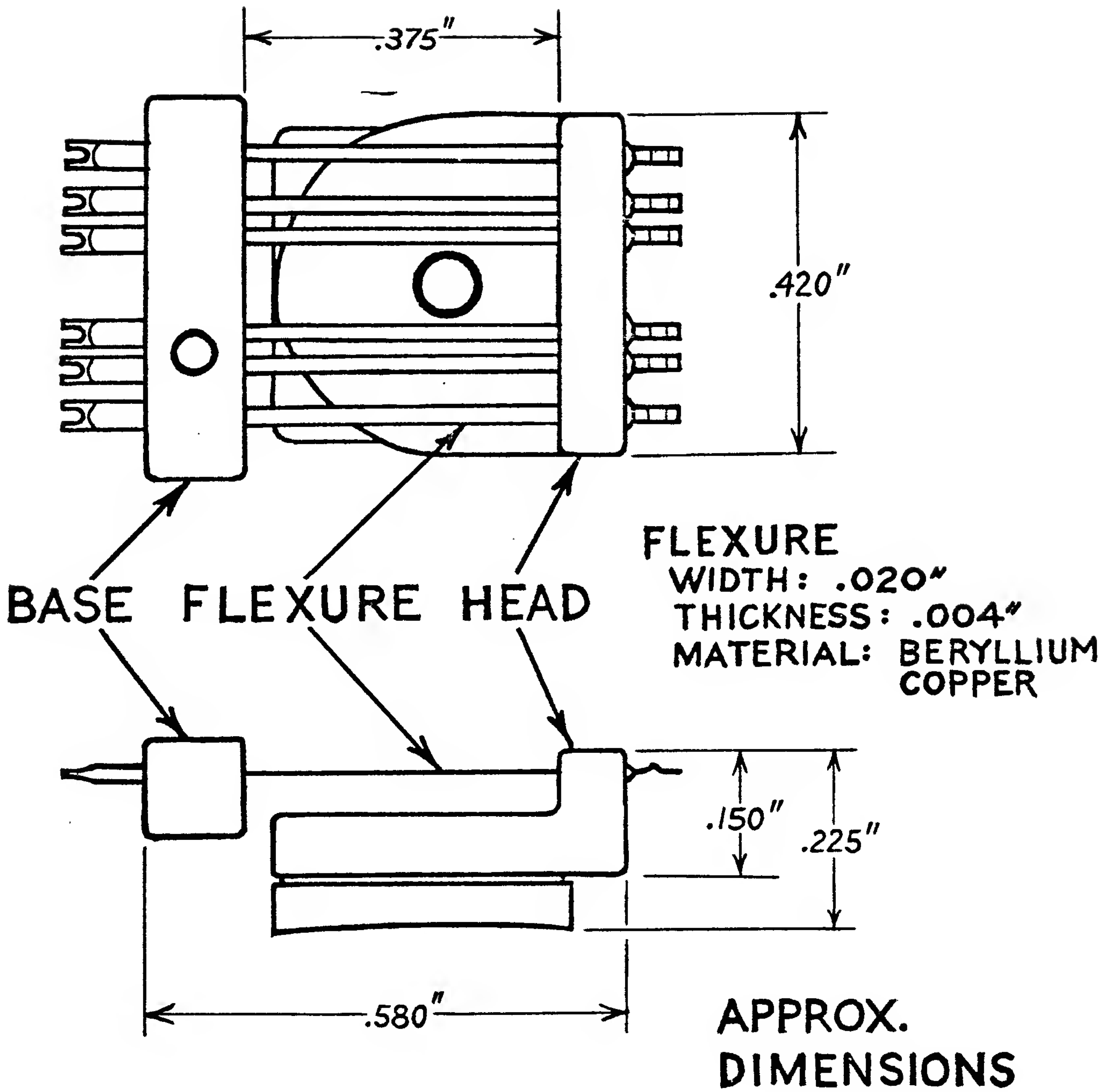

.375"
.420"
BASE
FLEXURE
HEAD
FLEXURE
WIDTH: .020"
THICKNESS: .004"
MATERIAL: BERYLLIUM COPPER
.150"
.225"
.580"
APPROX. DIMENSIONS

EXHIBIT 1-A

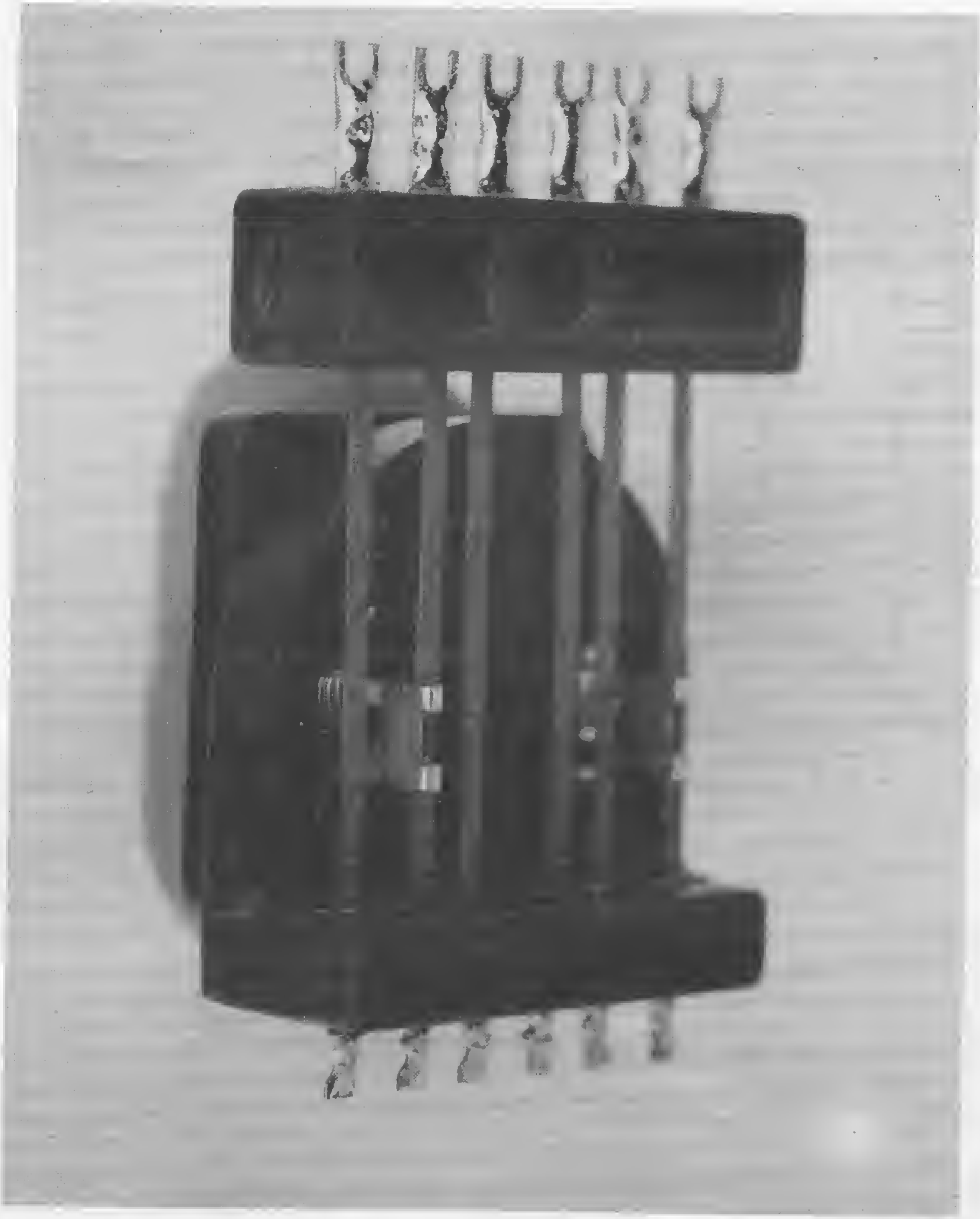
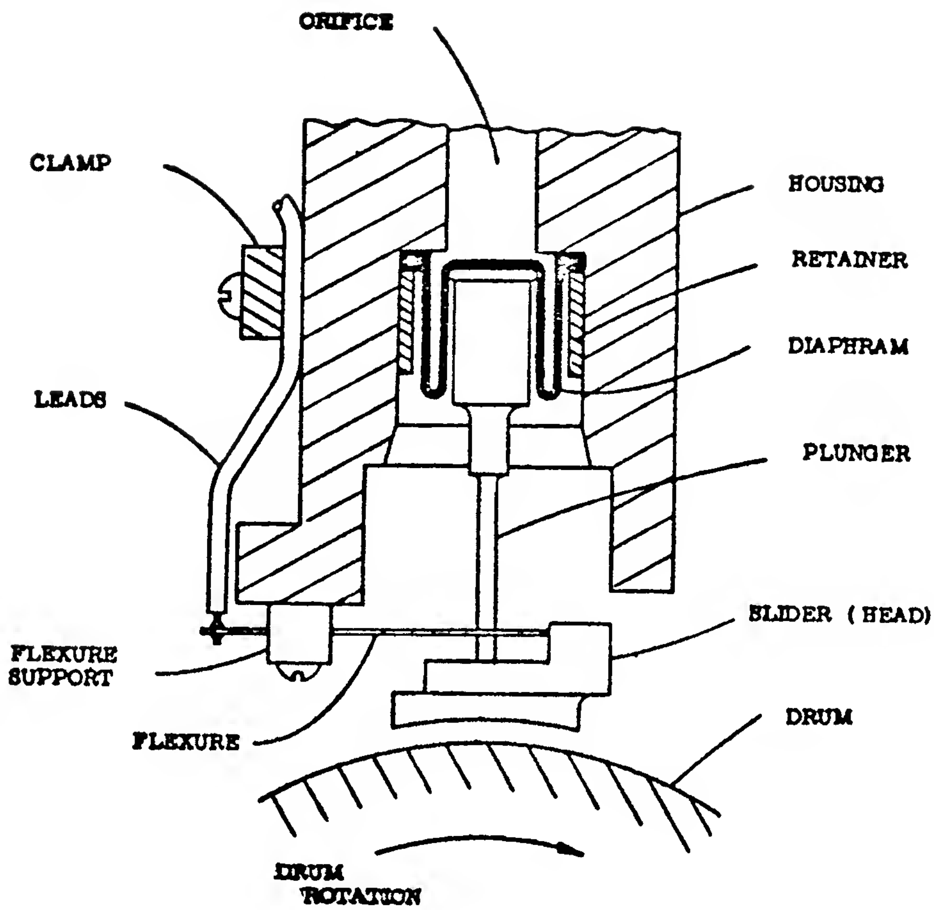
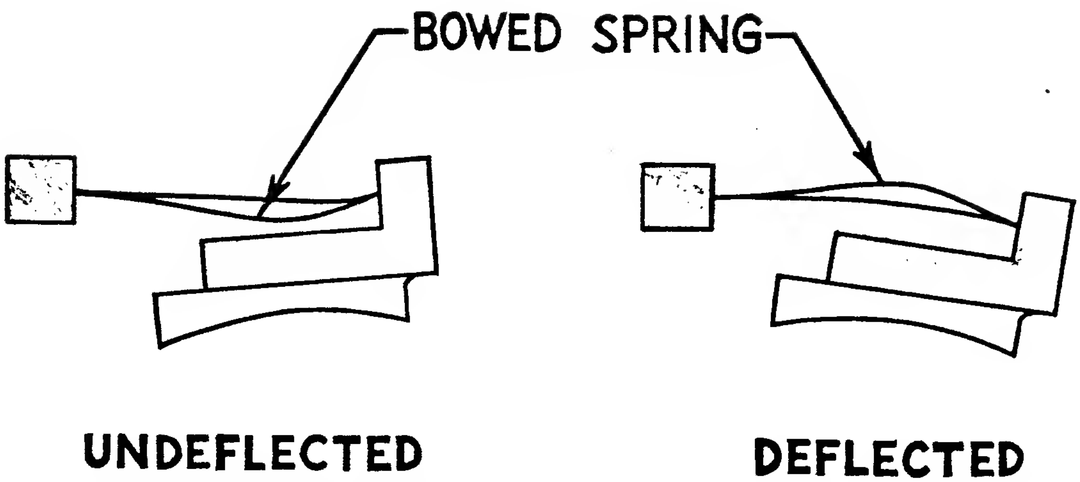


EXHIBIT 1-B

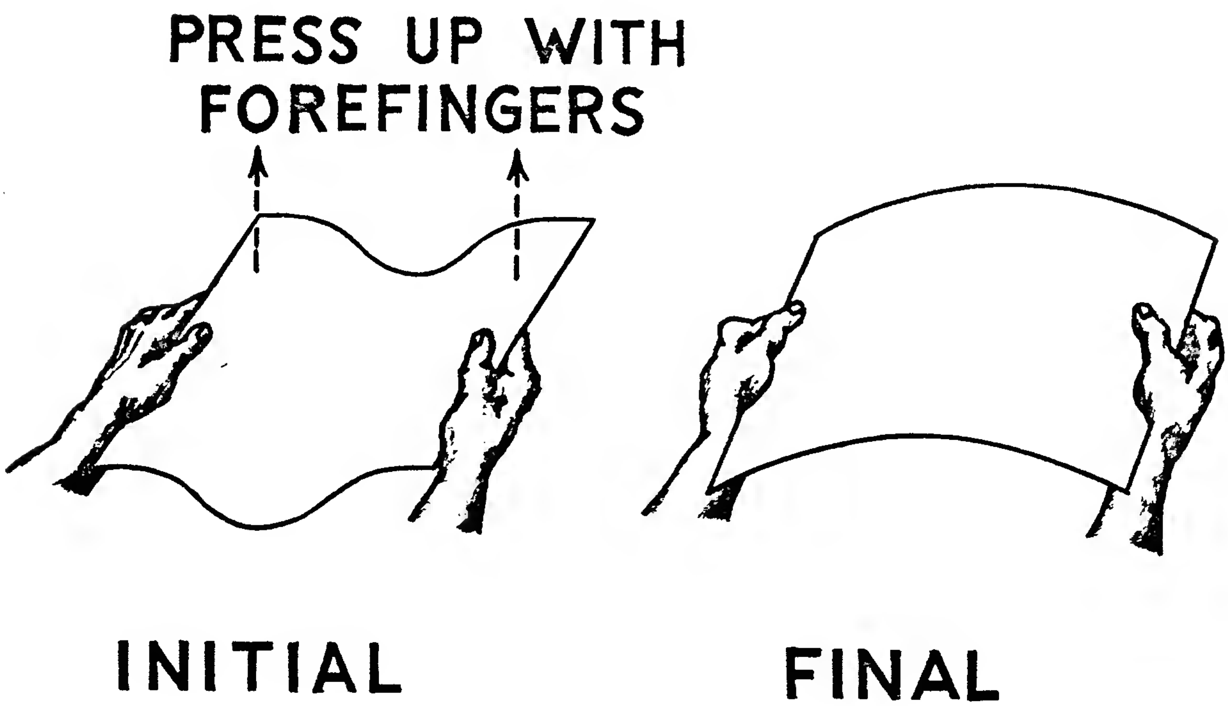


Head Suspension System

EXHIBIT 2



Oil can effect - initially bowed spring "pops" during flexure



Similar effect exhibited by a sheet of paper. A distinct change in the force felt at the fingers accompanies popping.

EXHIBIT 3

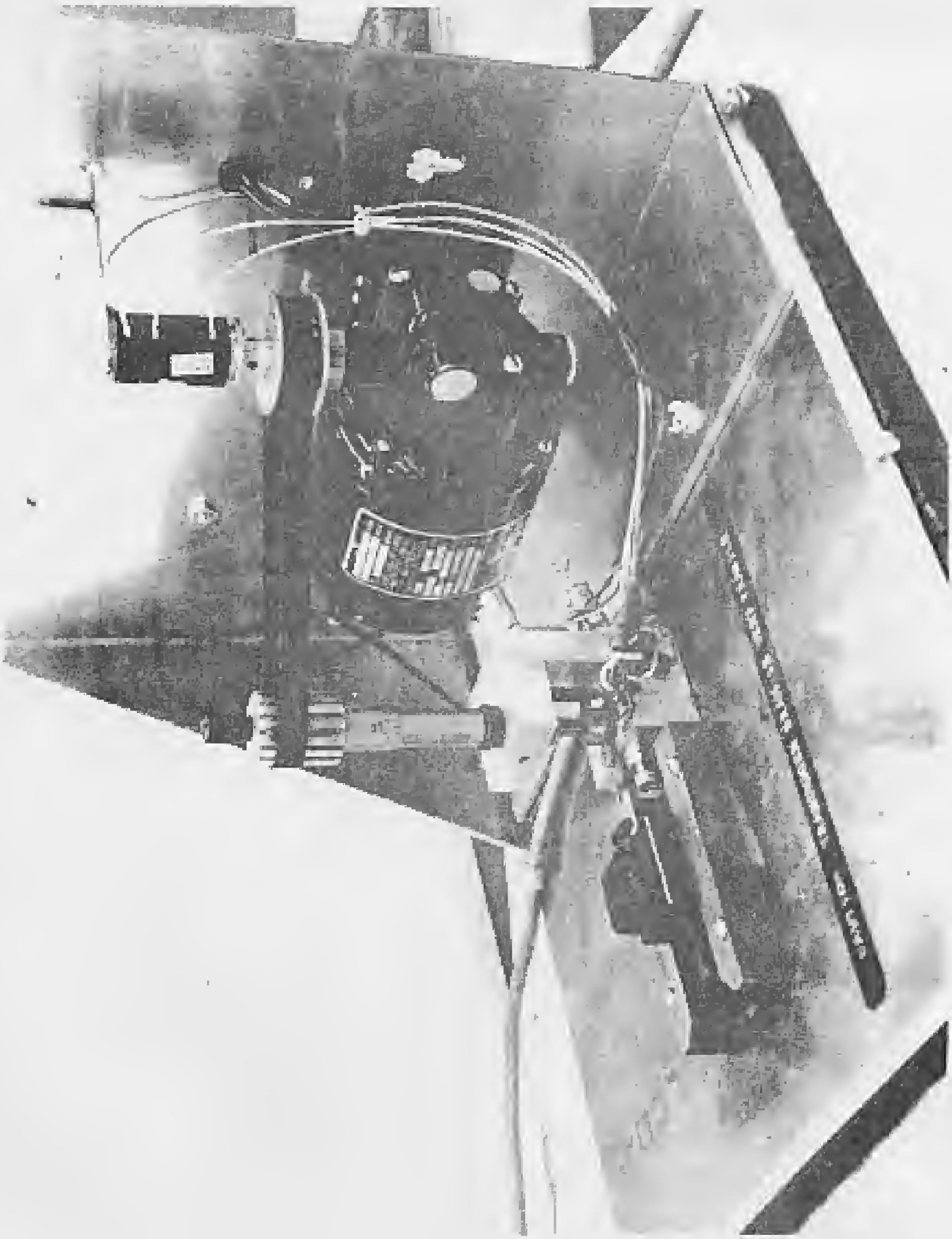
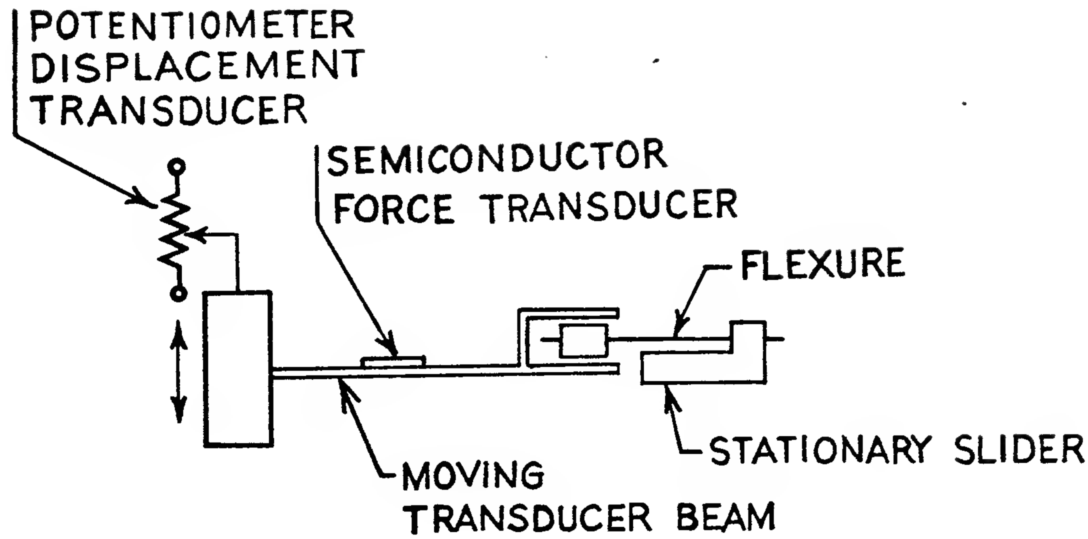
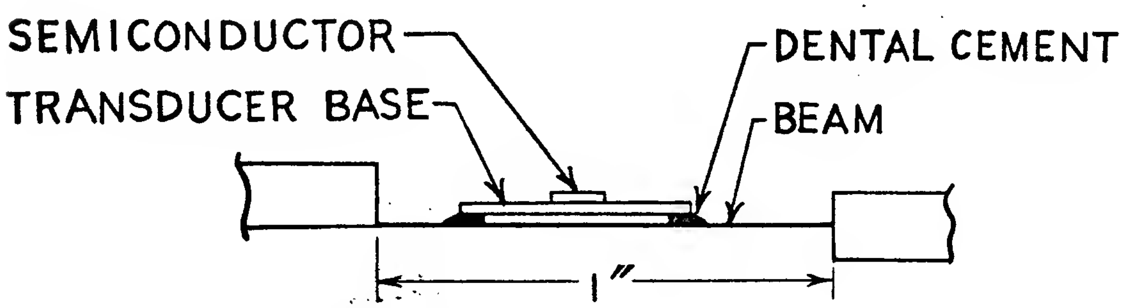


EXHIBIT 4-C



SCHEMATIC OF OIL CAN DETECTOR TRANSDUCER ARRANGEMENT

EXHIBIT 4-A



BEAM: 1″ x 1/8″ x .010″ SHIMSTOCK, STEEL
TRANSDUCER: ENDEVCO "PIXIE" MOD. 8103, 600 Ω

SCHEMATIC OF TRANSDUCER BEAM (SIDE VIEW)

EXHIBIT 4-B

Date:	June 6, 1968
From (location & address):	SDD San Jose Mechanical Analysis
Dept. & Bldg.:	494/026
Telephone Ext.:	3864

ECL 144

IBM

Subject: Measurements of Oil Canning of Slider Flexures

Reference: SR 494373

To: G. I. White
Department
San Jose

Our April 23, 1968 report describes an instrument we constructed for the detection of oil canning of slider flexures. Here we wish to describe the modification made on the instrument and the measurements performed with it.

The purpose of the modifications was to obtain a measure of the "strength" of the oil canning and thus to enable you to establish meaningful specifications in this area. The modifications consist of the addition of a transducer and circuitry to indicate the displacement of the flexure; addition of output circuits for connection to an oscilloscope. The revised circuit diagram is shown in Figure 1,* while the arrangement of the transducer components is illustrated schematically in Figure 2.**

Oil canning of a flexure causes a force transient which can now be observed on an oscilloscope connected to the instrument. The amplitude of the transient is indicative of the "strength" of the oil canning. The addition of a displacement output permits the specification of a maximum change of force ΔF within a given displacement ΔD. Calibration of the two outputs provides the following numbers:

Force:	33 gm/volt
Displacement:	.117 inch/volt

The displacement calibration takes into account the bending of the transducer beam due to the force applied at its end by a flexure of average stiffness.

Figures 3-10 contain force and displacement traces of 24 slider flexures, selected at random from the rejects supplied by you. The amplitude of the force transients in these oscillographs varies from 0.33 to 2.64 grams. In Table 1, each of the 24 sliders is characterized by a number ranging from 0 to 4,

* as shown in Exhibit 6
** as shown in Exhibit 4-A (ed.)

indicating the "strength" of the oil canning. Zero on this scale corresponds to no oil canning, while four means an extreme bi-stable condition. The numbers were arrived at from visual observation of the magnified flexures during their motion.

The oscillographs were obtained with the flexure ends moving at a velocity of 0.032 inches/second (No. 30 on the speed control dial). Small variations of the velocity do not affect the amplitude of the force transients.

Clarin Jako
C. Jako

CJ:dh

Attachments

c: K. Elser,
D. Palmer, 494/026

TABLE 1

2303 SLIDER FLEXURE OIL CAN MEASUREMENT

SLIDER NO.	OIL CAN "STRENGTH"	AMPLITUDE OF FORCE TRANSIENT (GRAMS)	NOTES
1	3	.99	Inconsistent
2	1-2	.50	
3	1	.41	
4	2	.41	
5	0	-	
6	1	.33	
7	0	-	
8	1	.33	
9	2-3	.99	
10	0	-	
11	1	.33	
12	0	-	
13	2	.50	
14	0	-	
15	3	.99	
16	0	-	
17	1	.50	
18	2	.83	
19	1	.50	
20	2	.66	
21	3	.83	
22	0	-	
23	4	2.15	No oil can on downstroke
24	4	2.65	

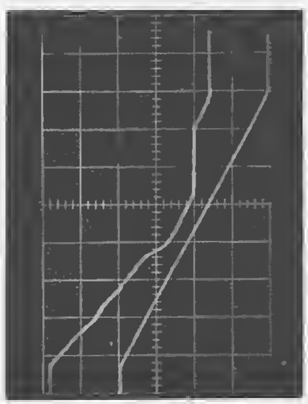
Force: Top trace, .05 volt/cm

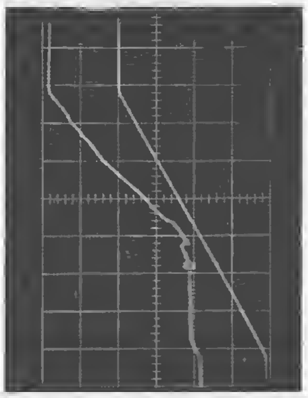
Displacement: Lower trace, .2 volt/cm

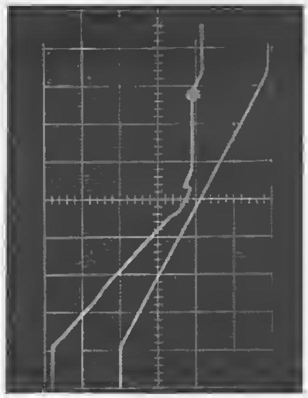
Sweep: Uncalibrated

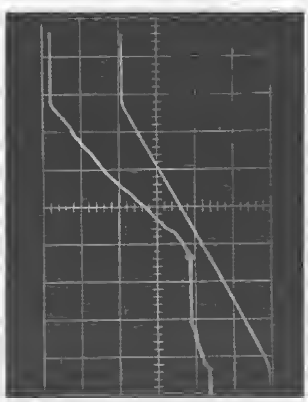
Oscillograph numbers correspond to slider numbers in Table 1 ("a" indicates up motion; "b" indicates down motion).

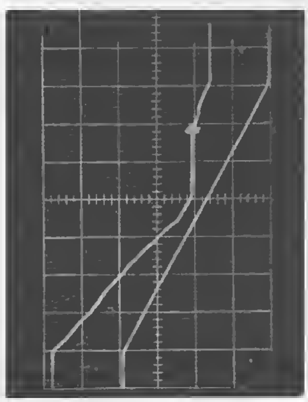

1a

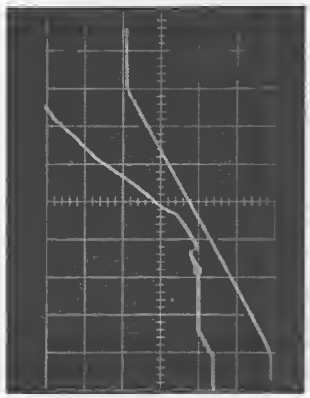

1b

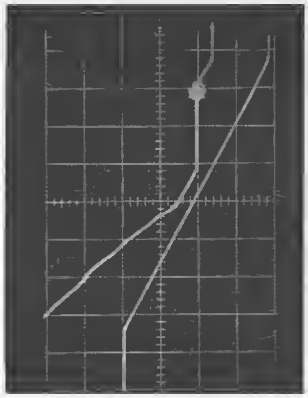

2a

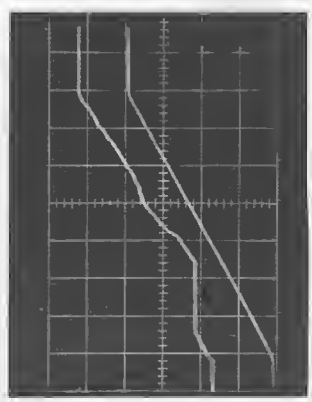

2b


3a


3b

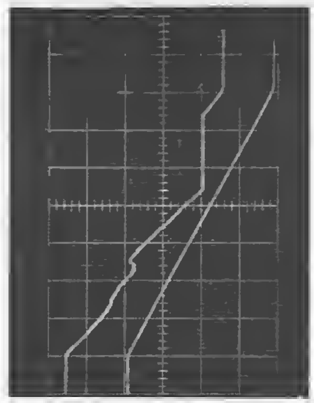

4a

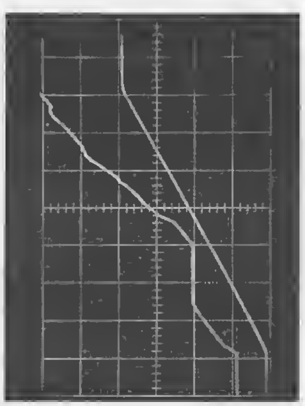

4b

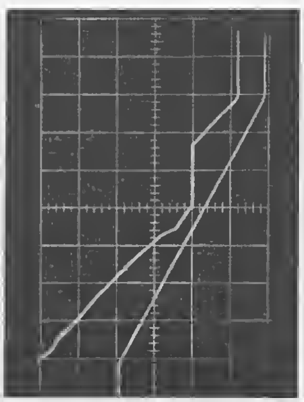

5a

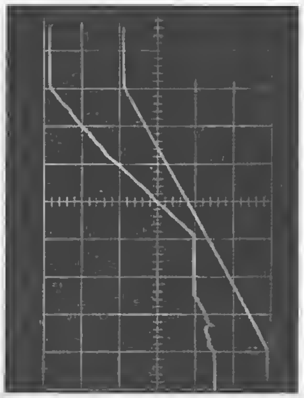

5b

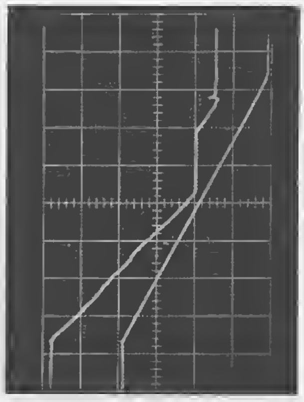

6a


6b

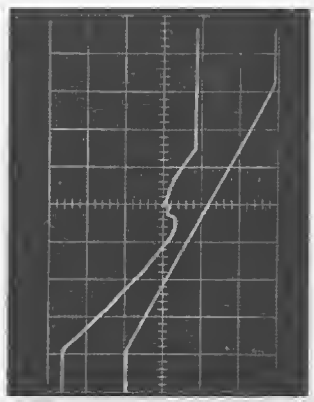
7a


7b


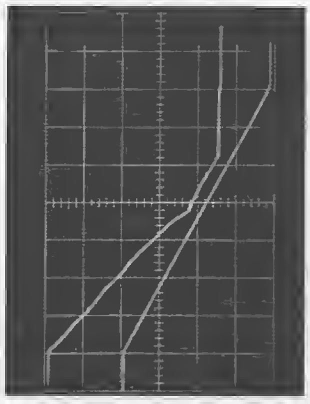
8a


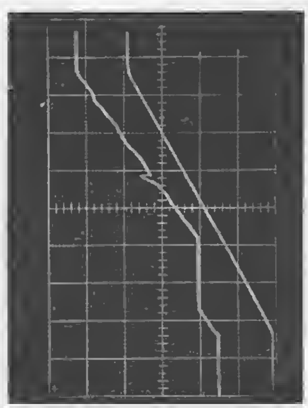
8b


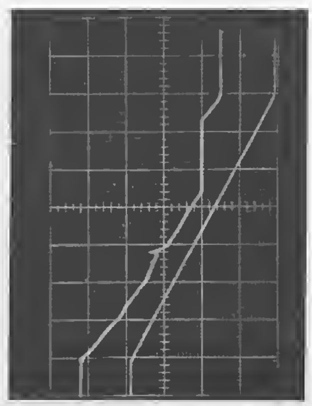
9a

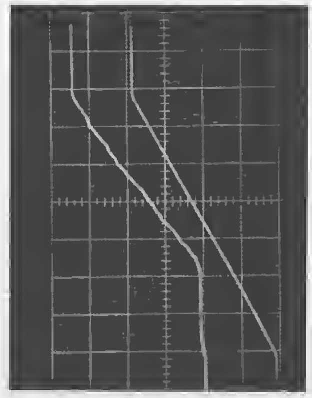

9b


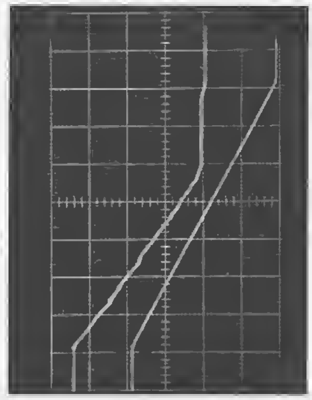
10a


10b


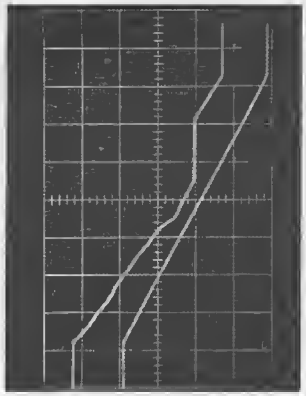
11a


11b


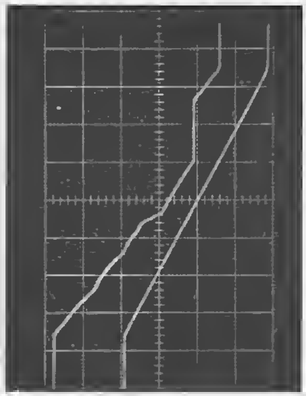
12a


12b


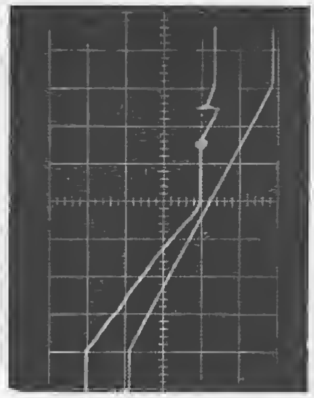
14b



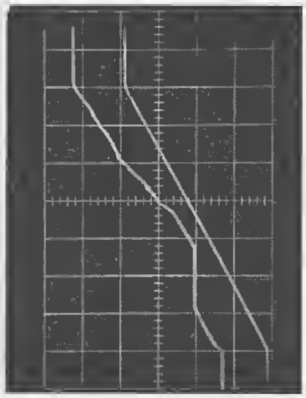
16b



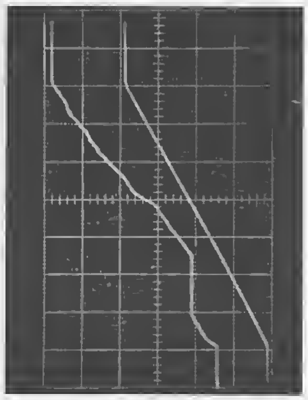
18b



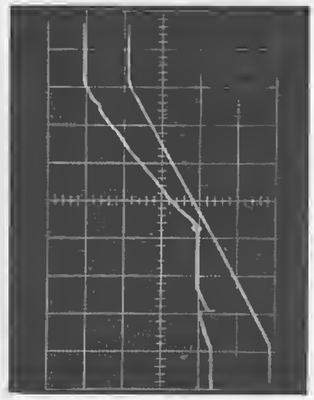
14a



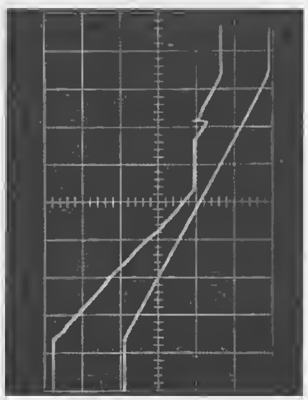
16a



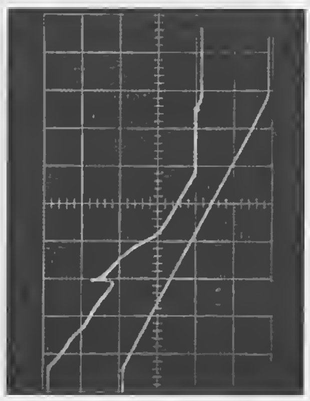
18a



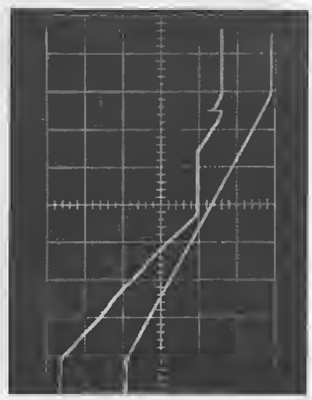
13b



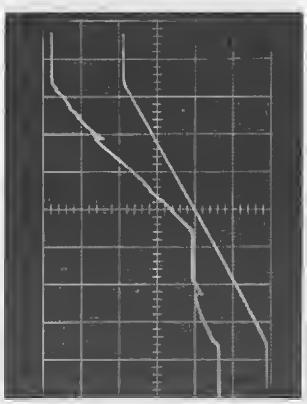
15b



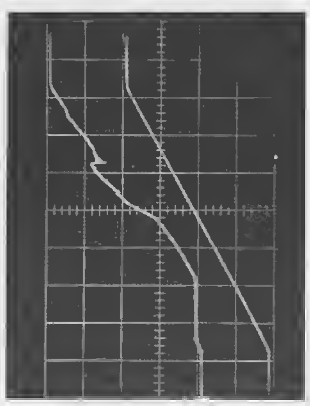
17b



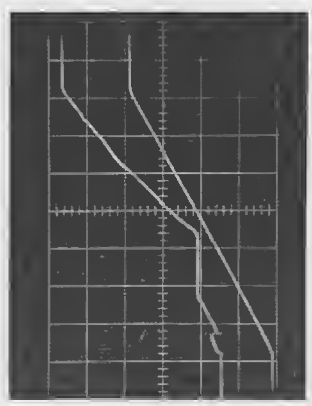
13a

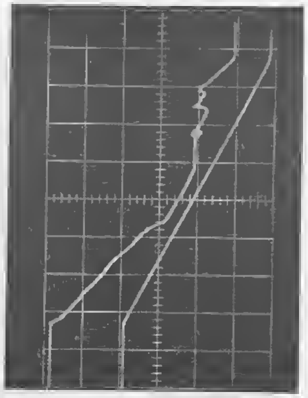


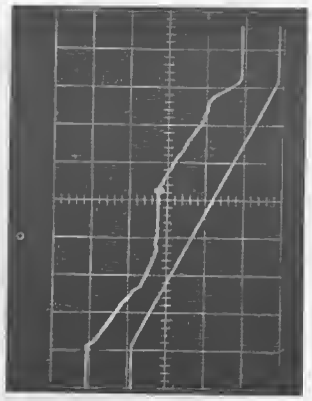
15a

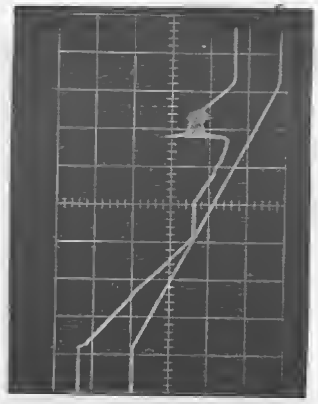


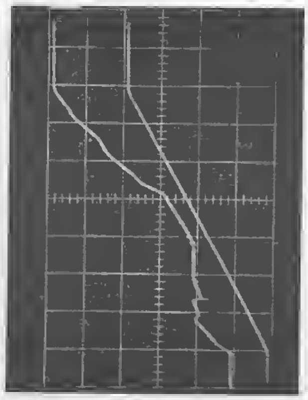
17a

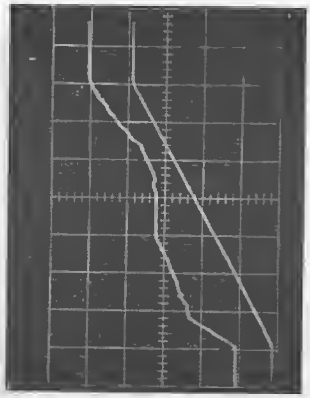


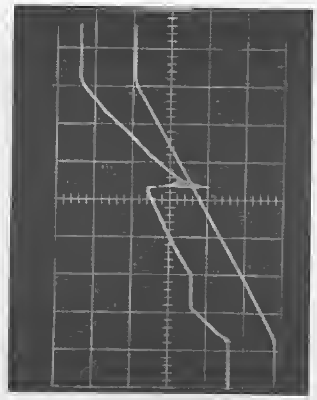
20b


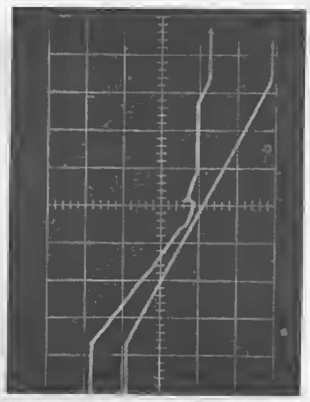
22b


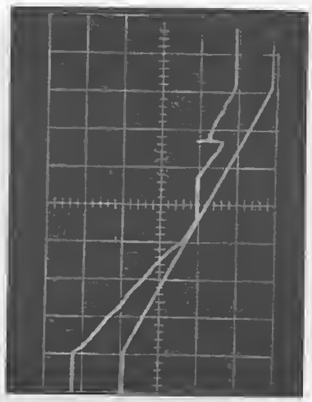
24b


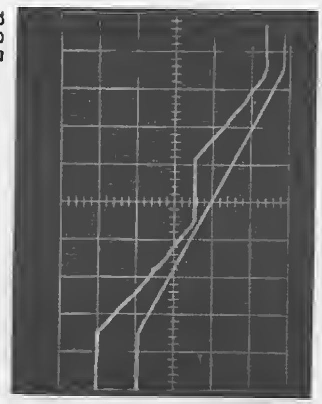
20a


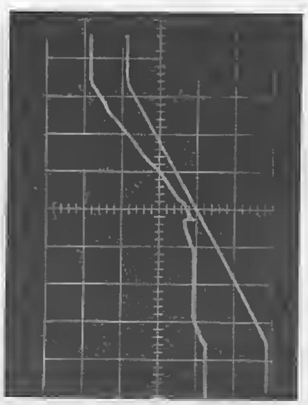
22a


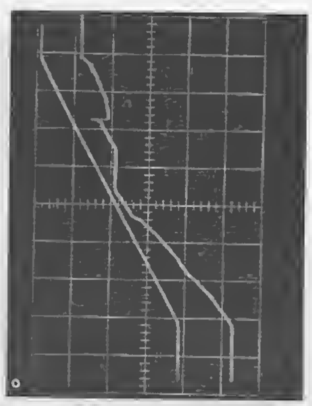
24a


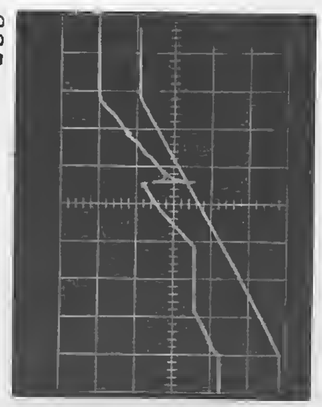
19b


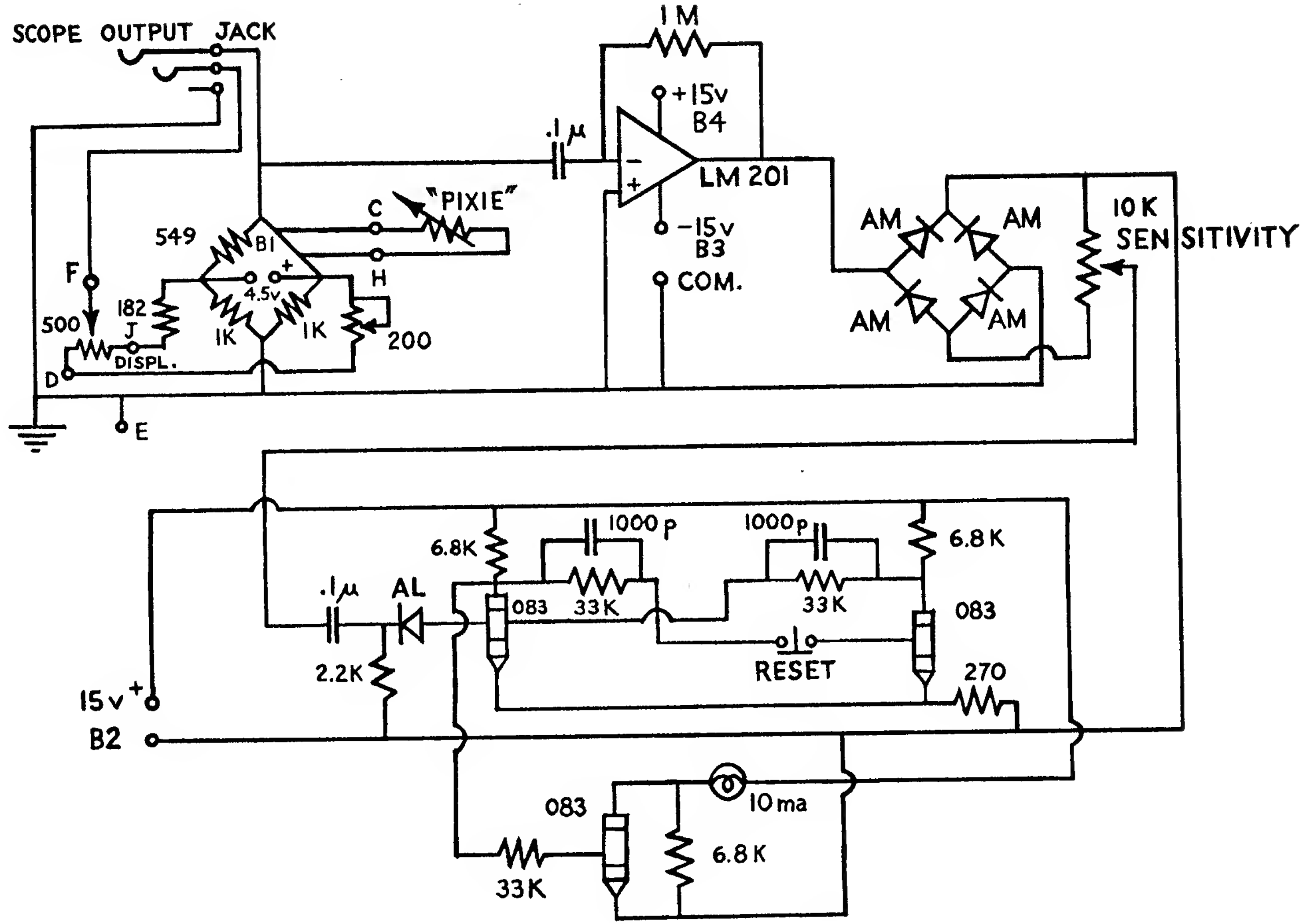
21b


23a


19a


21a


23b




CIRCUIT SCHEMATIC OF OIL CAN DETECTOR

EXHIBIT 6